US Army Corps
of Engineers

Field Guidance for Periodic Inspections of Coastal Structures

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PURPOSE: The Coastal Engineering Technical Note (CETN) herein reviews current procedures used by Corps of Engineers coastal Districts and Divisions relative to periodic inspections of their coastal structures and recommends standardized guidance to the field based upon the review and analysis.

INTRODUCTION: The Corps of Engineers' policy relative to periodic inspections of navigation structures is

> Civil Works structures whose failure or partial failure could jeopardize the operational integrity of the project, endanger the lives and safety of the public, or cause substantial property damage shall be periodically inspected and evaluated to ensure their structural stability, safety, and operational adequacy.

Engineer Regulation 1110-2-100 (U.S. Army Corps of Engineers 1995) describes periodic inspection responsibilities, procedures, and intervals for major Civil Works projects, such as locks and dams. The regulation states that the major subordinate commands are responsible for establishing periodic inspection procedures, intervals, etc., for other pertinent civil works structures.

During discussions at a recent program review for the Monitoring Completed Navigation Projects (MCNP) program, field review group members discussed periodic inspection procedures for coastal structures and determined that standard methods or recommended guidance relative to how and when these inspections should be conducted did not exist. Field review group members urged that a review of the current procedures be performed and that standardized or national guidance be provided the field. The work was recommended under the Periodic Inspections work unit of the MCNP program.

CURRENT FIELD PERIODIC INSPECTION PROCEDURES: Coordination with various Corps of Engineers District offices along the Pacific, Atlantic, Gulf, and Great Lakes coasts revealed major differences in the procedures used for periodic inspections of coastal structures. Various procedures currently used by the field are shown in the following subparagraphs:

Some Districts perform walking inspections on all their coastal structures annually and calculate condition indices (U.S. Army Corps of Engineers 1996) for each structure based on the methodology developed as part of the Repair, Evaluation, Maintenance, and Rehabilitation Research program.

Some Districts perform walking inspections of their coastal structures annually, but do not calculate condition indices.

Some Districts perform annual walking inspections of only their recently constructed coastal structures. Older structures, however, are omitted from annual inspections and have less frequent inspection intervals.

Some Districts conduct multilevel side scans of breakwater slopes and aerial photogrammetry on 5- to 10-year intervals as well as annual walking inspections.

Some Districts only obtain aerial photography of their structures. The frequency varies, but most are annually.

Some Districts conduct walking inspections on 2-year intervals and calculate condition indices.

Some Districts perform walking inspections of their coastal structures every other year (2-year intervals) and do not calculate condition indices.

Some Districts conduct walking inspections on 3-year intervals if the structure has not changed for 4 consecutive years.

Some Districts conduct walking inspections of their structures only when personnel are in the field and in the vicinity.

Some Districts only observe structures while in the area for other purposes. The observations do not include walking inspections.

Some Districts perform walking inspections of their structures only after major storm events.

Some Districts perform walking inspections of their structures only after a problem is reported by local users.

As shown, the frequency and type of periodic inspections vary throughout the Corps. Most Districts do not have formal periodic inspection programs in place for their coastal structures, but several are in the process of developing these programs.

FACTORS THAT INFLUENCE INSPECTION FREQUENCY: The following factors may influence the inspection frequency of coastal structures:

a. The geographic area.

b. The environment.

c. The age of the structure.

d. The history of the structures.

e. Major storm events.

f. Funding and manpower.

The geographic area in which the structure is exposed is a major factor. Structures located along the Pacific coast are subjected to more energetic events than structures located in bays or along the Gulf of Mexico coast. Additionally, structures on the Great Lakes or in Alaska experience freeze/thaw conditions that affect stone quality and require closer attention than structures in milder climates. Structures exposed to harsh, severe environments generally need to be inspected more often than those located in less energetic climates.

Recently constructed, rehabilitated, or repaired structures may require more frequent monitoring than older structures that have a history of good stability. Frequent inspections of newer structures are necessary to develop an information base for the structure(s) and determine the response of the new construction to its environment. Structures with a recurring history of repairs may also require more frequent inspections.

Structures should be inspected after major storm events or other events that may potentially cause damage to the structure (i.e., earthquake, ship collision). In addition, if the risk of a damaged structure affects navigation, property, and life, more frequent inspections are warranted. Structures in the Honolulu District, for example, are inspected annually because many of the structures protect the only harbor or channel to a specific island. Loss or damage to the structure could result in loss of shipping to the island and may require air shipment of necessities.

Available funding and manpower may dictate the frequency of inspections, especially in Districts that have numerous coastal structures.

METHODS OF CONDUCTING PERIODIC INSPECTIONS: Periodic inspections of coastal structures may be performed in a variety of ways. Both formal and informal methods may be utilized. Formal monitoring may include a photogrammetric analysis of armor unit positions (U.S. Army Engineer Waterways Experiment Station 1984, 1994) and detailed broken armor unit surveys for above-water portions of the structure. For areas below the water surface, side-scan sonar records or SEABAT methodology (Prickett 1996) may be employed. Airborne lidar technology such as provided by the SHOALS system may be utilized to monitor structures both above and below the water surface (Parson and Lillycrop 1998). Informal methods may consist of walking surveys, surveys by boat, aerial photography, and casual observations.

Photogrammetric analysis usually yields detailed, rectified photo maps of the armor unit positions above the water level. Above-water cross sections and contours of the structure may also be obtained. Detailed broken armor unit surveys entail the locations of broken armor units as well as the types of breaks and individual photographs of the armor units. Side-scan sonar and SEABAT records may be analyzed to determine the condition of the structure below the water surface. Cross sections and contours may be obtained. Formal monitoring yields quantifiable data that can be used for comparison with subsequent surveys.

Performing periodic inspections on coastal structures may, at times, require the collection and use of hydrographic survey data coupled with topographic survey data. SHOALS technology provides the ability to simultaneously collect both kinds of information at considerably high resolutions. When used for surveying structures, the capabilities provided by SHOALS allow for complete survey coverage up to 100 percent above and below the waterline. The data can be used to create various products enabling structural evaluation of features such as crest elevation, side slopes, toe and armor stone position, and areas of potential breaching. Cross sections and topography of the structure may also be produced as well as video footage enabling visual inspection and other remote measurements to be extracted.

Walking inspections are an expedient and effective means of determining if structures are experiencing deterioration or settlement and of observing voids, breaches, and armor unit cracking, spalling, and breakage. Some structures may not be accessible by land or may be detached and require accessibility by boat. Surveys by boat are effective in determining the condition of the structure; however, shallow water close to shore may prevent inspection in those areas. Arrangements also must be made to have a boat available prior to the inspection. Aerial photography may provide images that can be compared with prior photography, but usually does not provide detailed conditions of the structures' components. Casual observations while in the area for other purposes usually are not very detailed and may only detect major structural deterioration. These methods of observation relate to the above-water portion of the structure. Problems observed above the water may be a basis for dive inspections to determine the general underwater condition of the structure.

The methods used for periodic inspections of coastal structures should be selected by District personnel based on the repair history of the structure, past experience, engineering judgment, and available funding and manpower.

COASTAL STRUCTURE PERIODIC INSPECTION GUIDANCE: Many factors contribute to the frequency of periodic inspections on Corps' structures in the United States. Because of the diverse geographic and environmental conditions in different regions of the country, all factors do not apply to each structure. Defining specific guidelines for periodic inspections that encom-pass all the structures is difficult. In general, the frequency of inspection of a particular structure should be determined on a case-by-case basis. General guidance for the development of an inspection schedule is shown below:

Annual inspections should be conducted for recently constructed, rehabilitated, or repaired structures that are subjected to harsh wave conditions as well as coastal structures with a long, recurring repair history. If the structure is located in an environment in which typical wave conditions are not severe, inspections should be conducted every 2 to 3 years. If no significant damage occurs to the structure after 5 years, less frequent inspections may be appropriate. All inspections should be documented to provide information and guidance for future assessments.

The risk to navigation, property, and life associated with a damaged structure should be considered in inspection frequency. Annual inspections should be considered for structures in

which annual storm events can damage the structure and result in loss of life, property, or disruption in navigation that would halt shipment of necessities to the region.

Stone integrity is a problem for structures located in freeze/thaw environments. Structures in these locations should be inspected no less than every other year, and stone integrity should be assessed closely.

Inspections should follow major storms or other events that could result in structural damage. In addition, reports of damage by local users of the project should be investigated immediately.

Cost is a factor that limits the frequency of inspections. A possible solution to defray costs is to conduct inspections jointly with other Federal or pertinent State agencies and to take advantage of opportunities when other data collection is scheduled in the immediate area. Additionally, inspection costs should be considered in the District's Operation and Maintenance budget.

SUMMARY: Most Corps of Engineers Districts have not developed formal periodic inspection programs for their coastal structures, and the frequency and type of inspections vary significantly throughout the Corps. The coastlines and environment of the United States are diverse, and the response of coastal structures differ greatly from location to location. The type and frequency of inspections of structures should be selected on a case-by-case basis during the development of the periodic inspection program. In general, structures subjected to major storm events and those that suffer frequent damage should be inspected more often than those located in milder environments with a history of stability. Documentation of observations and inspections is vital for comparison to subsequent assessments.

ADDITIONAL INFORMATION: For additional information contact Mr. Ernest R. Smith, Coastal and Hydraulics Laboratory, at 601-634-4030 or e-mail *Ernest.R.Smith@erdc.usace.army.mil*.

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